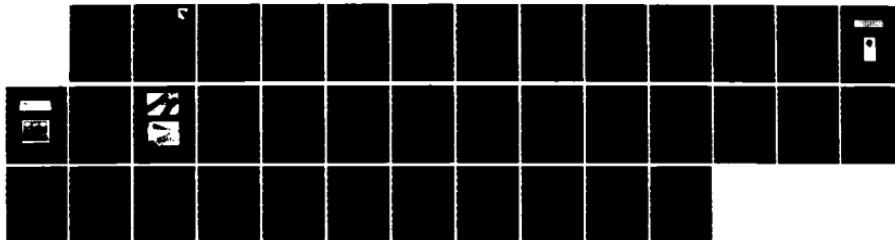
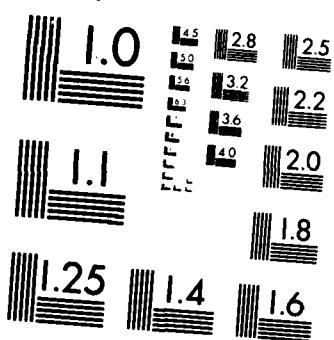


AD-A173 545 DEXTERITY TESTING OF CHEMICAL DEFENSE GLOVES(U) 1/1
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**DEXTERITY TESTING OF
CHEMICAL DEFENSE GLOVES (U)**

KATHLEEN M. ROBINETTE

HARRY G. ARMSTRONG AEROSPACE MEDICAL RESEARCH LABORATORY

*CAY ERVIN
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ANTHROPOLOGY RESEARCH PROJECT, INC.

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AAMRL-TR-86-021

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER


CHARLES BATES, JR.
Director, Human Engineering Division
Armstrong Aerospace Medical Research Laboratory

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED		1b. RESTRICTIVE MARKINGS	
2a. SECURITY CLASSIFICATION AUTHORITY		3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.	
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE			
4. PERFORMING ORGANIZATION REPORT NUMBER(S) AAMRL-TR-86-021		5. MONITORING ORGANIZATION REPORT NUMBER(S)	
6a. NAME OF PERFORMING ORGANIZATION HARRY G. ARMSTRONG AEROSPACE MEDICAL RESEARCH LABORATORY	6b. OFFICE SYMBOL (If applicable) HEG	7a. NAME OF MONITORING ORGANIZATION	
6c. ADDRESS (City, State and ZIP Code) AAMRL/HEG Wright-Patterson AFB, OH 45433		7b. ADDRESS (City, State and ZIP Code)	
8a. NAME OF FUNDING/SPONSORING ORGANIZATION	8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER F33615-82-C-0510	
8c. ADDRESS (City, State and ZIP Code)		10. SOURCE OF FUNDING NOS	
		PROGRAM ELEMENT NO. 62202F	PROJECT NO. 7184
		TASK NO. 08	WORK UNIT NO. 39
11. TITLE (Include Security Classification) DEXTERITY TESTING OF CHEMICAL DEFENSE GLOVES (U)			
12. PERSONAL AUTHORIS Kahtleen M. Robinette, Cay Ervin* and Gregory F. Zehner*			
13a. TYPE OF REPORT Technical	13b. TIME COVERED FROM _____ TO _____	14. DATE OF REPORT (Yr., Mo., Day) 1986 MAY	15 PAGE COUNT 36
16. SUPPLEMENTARY NOTATION * Anthropology Research Project, Inc. 503 Xenia Avenue, Yellow Springs, OH 45387			
17. COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) Gloves Chemical Defense Dexterity	
19. ABSTRACT (Continue on reverse if necessary and identify by block number) Four types of chemical defense gloves (12.5 mil Epichlorohydrin/Butyl, 14 mil Epichlorohydrin/Butyl, 14 mil Butyl and 7 mil Butyl with Nomex overgloves) were evaluated for their effect on hand dexterity. Fifteen male and 15 female subjects performed four dexterity tests (O'Connor Finger Dexterity Test, Pennsylvania Bi-Manual Worksample-Assembly, Minnesota Rate of Manipulation Turning, and the Crawford Small Parts Dexterity Test-Screws) bare-handed and while wearing the chemical defense gloves. Results indicated that subjects' performances were most impaired by the 7 mil Butyl with Nomex overglove. Though differences between the other three gloved conditions were not always statistically significant, subjects performed slightly better while wearing the Epichlorohydrin/Butyl gloves, no matter which thickness, than they did while wearing the 14 mil Butyl gloves. High negative correlations between anthropometry and gloved test scores of subjects suggested that poor glove fit may also have affected subjects' performances. (continued on reverse side)			
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT. <input checked="" type="checkbox"/> DTIC USERS <input type="checkbox"/>		21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED	
22a. NAME OF RESPONSIBLE INDIVIDUAL KATHLEEN M. ROBINETTE		22b TELEPHONE NUMBER (Include Area Code) 513-255-8810	22c OFFICE SYMBOL AAMRL/HEG

19. ABSTRACT (cont'd)

The authors recommend development of a standardized dexterity battery for testing gloves. Noting that the tests used in this study were chosen because they were readily available, the authors suggest that future efforts should include examination of the widest possible range of existing dexterity tests.

SUMMARY

The following study examined the effects of chemical defense gloves on hand dexterity. Four types of gloves (12.5 mil Epichlorohydrin/Butyl, 14 mil Epichlorohydrin/Butyl, 14 mil Butyl, and 7 mil Butyl with Nomex overglove) were compared to bare-handed performance on four dexterity tests (O'Connor Finger Dexterity Test, Pennsylvania Bi-Manual Worksample-Assembly, Minnesota Rate of Manipulation Turning, and the Crawford Small Parts Dexterity Test-Screws).

As expected, subject performance was significantly the worst while wearing the Nomex overglove, probably due in large part to a decrease in mobility caused by wearing three layers of gloves. Of the three remaining gloved conditions, performance seemed less impaired by both Epichlorohydrin/Butyl gloves (12.5 mil and 14 mil thick) than by the 14 mil Butyl gloves, but the results were not always significantly different. Though performance was more adversely affected by the Butyl gloves, these gloves did not show signs of wear as the Epichlorohydrin/Butyl gloves did.

For both men and women there were no significant correlations between anthropometry and bare-hand performance. While wearing gloves, however, the correlations ranged from -.40 to -.91. These results indicate that glove fit significantly affected test scores. Further research is recommended to more accurately identify the fit problem by testing each person in all sizes. By improving glove fit, performance while wearing gloves would more closely approximate bare-hand performance.

Prior to this study, extensive work had been conducted to review and modify available tests, and to develop an experimental design which would control learning effects. The experimental design and modified test procedures are described in the text. Further work in developing a standardized battery of tests is recommended in order to decrease the need for extensive pilot testing and to facilitate comparisons of results.



A1

PREFACE

This study was conducted by the Anthropology Research Project, Inc. under Air Force Contract F33615-82-C-0510 (Project 718408) with the U.S. Air Force Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio.

The authors would like to thank Captain Jerry Brown, Aerospace Medical Division, Brooks Air Force Base, for his support of the project and for providing the gloves worn by the subjects during testing. They also wish to acknowledge Ms. Donna Bagdonovich for supplying the glove liners and for her helpful suggestions.

Ms. Ilse Tebbetts and Ms. Jane Reese, Anthropology Research Project, edited and prepared the manuscript for publication.

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DEXTERITY TESTING OF CHEMICAL DEFENSE GLOVES

INTRODUCTION

The goal of this study was to determine the relative effects of four different types of chemical defense (CD) gloves on hand dexterity. While a number of tests for evaluating gloves have been developed and conducted over the past 25 years, they have varied considerably in purpose, format, and method of administration. No one appears to have developed or documented a standard set of tests or procedures designed to test dexterity. (A list of publications which were reviewed for this study is included in the bibliography.) For this reason, considerable attention was devoted to the tests themselves.

In an earlier study,* a set of readily available dexterity tests had been used to evaluate performance of subjects in several CD glove types. Due to time constraints, limitations on the availability of glove sizes, and the use of an all-male sample, conclusions from that study were tentative at best. Its chief benefit for purposes of the present investigation was to pinpoint areas which required attention and improvement. A considerable amount of pre-testing was undertaken to review the test instruments at hand for evaluating dexterity, and to establish valid test procedures before the final test battery was selected and administered. It should be noted that the candidate tests from which the final battery emerged did not represent an exhaustive inventory of all commercially available tests, but included only those which were used in the earlier study. Future efforts aimed at developing a definitive battery should include examination of the widest possible range of available dexterity tests.

The battery developed here was used to compare scores of 30 subjects without gloves and while wearing each of the following glove types:

- 12.5 mil** Epichlorohydrin/Butyl (EB 12.5)
- 14 mil Epichlorohydrin/Butyl (EB 14)
- 14 mil Butyl (B 14)
- 7 mil Butyl with Nomex overglove (B 7/Nomex)

Results indicate that subjects tended to perform best without gloves (as expected) and better with either of the two EB gloves than with the other gloves. Analysis of the test results also suggested that not only glove type but glove fit significantly affected performance. Procedures and results of the test are fully described in the following chapters.

* Robinette, K.M., C. Ervin and G.F. Zehner, 1985, Attachment A "Preliminary Study," to Appendix 2, Final Report for Air Force Contract F33615-82-C-0510, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio. Unpublished.

** mil=1/1000 of an inch material thickness.

CHAPTER I

TEST PROCEDURES AND EXPERIMENTAL DESIGN

DEVELOPMENT OF THE TEST BATTERY

To select the tests and to standardize test procedures, subjects (co-workers) performed the candidate tests repeatedly with and without the various glove types. Subjects were queried about their reactions to the length of the tests, asked whether they felt they were still improving, and invited to comment in general on the tests and gloves. The tests were modified gradually and after each modification fresh subjects were used to evaluate the new versions.

Candidate tests included:

- Bennett Hand Tool Test (Bennett)
- O'Connor Finger Dexterity Test (O'Connor)
- Pennsylvania Bi-Manual Assembly (Pennsylvania)
- Pennsylvania Bi-Manual Disassembly (Pennsylvania Disassembly)
- Crawford Small Parts Dexterity Test-Screws (Crawford)
- Minnesota Rate of Manipulation Turning Test (Minnesota)

Two of these, the Bennett Test and the Pennsylvania Disassembly Test, were discarded after brief review. The Bennett Test was long and difficult to standardize. Furthermore, two of the remaining tests (Pennsylvania and Crawford) appeared to test similar functions with greater precision. The Pennsylvania Disassembly Test was dropped because it was so similar to the Pennsylvania Assembly Test and seemed redundant for our purposes.

With the exception of the Minnesota test, all of the candidate tests involved placing objects into rows of holes. It shortly became clear that these tests should be shortened. This was done by reducing the number of rows until one run-through took approximately three minutes or less. The results indicated that the shorter amount of time was still sufficient to discriminate between glove types while considerably lessening the boredom and frustration of the subjects.

After the test lengths were established, the administration of practice sessions was evaluated. The number of rows required for practice sessions was set considerably below the number required for test sessions for all but the Minnesota Test which was already very short. The learning curve seemed to level off (scores stabilized) after three to six runs. Therefore, six practice runs were decided upon for each test. (It should be noted that these practice runs were not completely randomized. Recent evidence [Dr. Dan Fisk, Wright State University Symposium, February 12, 1985] indicates that ordered presentation of practice by level of difficulty improves learning.)

Again, the test procedures were evaluated so that the order of presentation of each test could be established. This preliminary run also served to work out last-minute hitches in the test administration.

EXPERIMENTAL DESIGN

Tests

Four dexterity/tactility tests were used. The tests and the modifications made for this evaluation are described below. Instructions given to the subjects are included in Appendix A.

The Minnesota Turning Test (Figure 1) is a two-handed test. The object is to turn the blocks over, picking them up with one hand and putting them back bottom side up with the other as quickly as possible. This was the only test of the four which was not shortened.

The O'Connor Finger Dexterity Test (Figure 2) is a one-handed test (the dominant hand is used) in which the subject picks up three pins at a time and inserts them into one hole. The test board has 10 rows with 10 holes each. For practice runs, subjects completed one row, and for the actual test, four rows.

In the Pennsylvania Bi-Manual Assembly Test (Figure 3), the subject picks up a bolt with the dominant hand, and a nut with the other hand, then puts the nut and bolt together and places the assembled unit in a hole. The board contains 10 rows of 10 holes each. For this study, subjects completed one row for practice runs and four rows for testing.

The Crawford Small Parts Dexterity Test-Screws (Figure 4), involves use of the fingers to thread a small screw into a hole, and use of a screwdriver to turn it through. The board contains six rows of six holes each. Subjects completed one row for practice, and two rows for the actual test. The other subtest, Pins and Collars, was not used in this study.

Subjects

The 30 subjects (15 males and 15 females) were paid volunteers from an established subject pool. The majority of the subjects were undergraduate students from Wright State University, many of them in the Reserve Officer's Training Corps (ROTC). This is noteworthy because the college students appeared to be more highly motivated than the non-students, and the ROTC students appeared to be the most highly motivated of all. The age range of male subjects was 18 to 31 years (mean age: 22); the females ranged from 18 to 30 years (mean age: 21). Two females and one male were left-handed. Three females had participated in prior dexterity studies and three males had participated in the study cited in the INTRODUCTION.

Gloves

Four glove types were tested against the bare-handed condition. These gloves were the EB 12.5, the EB 14, the B 14, and the B 7/Nomex. The B 14 and the B 7/Nomex are currently used by Air Force ground crew and aircrew, respectively.

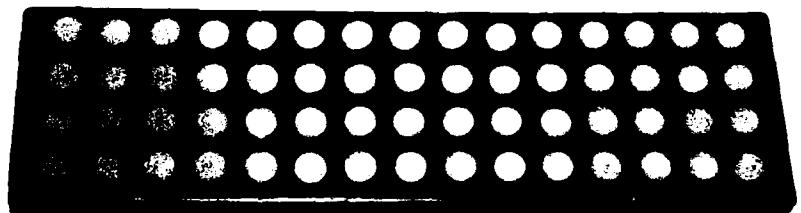


Figure 1. Minnesota Rate of Manipulation Test.



Figure 2. O'Connor Finger Dexterity Test.

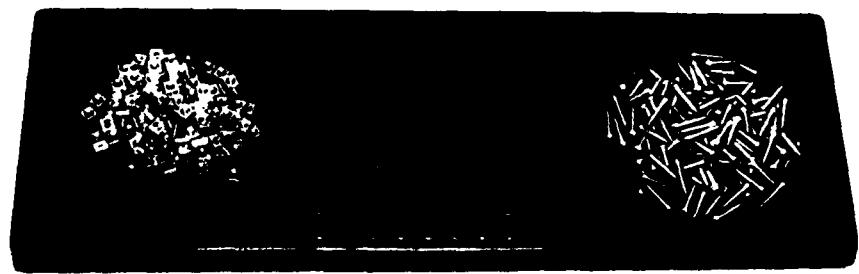


Figure 3. Pennsylvania Bi-Manual Test.

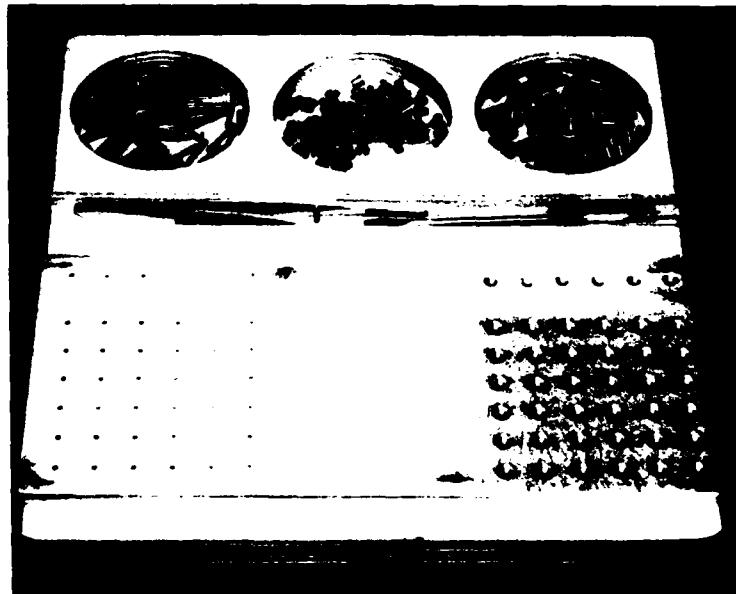


Figure 4. Crawford Small Parts Dexterity Test.

The total range of available sizes of the CD gloves was used. This included sizes X-Small, Small, Medium, Large and X-Large (Table 1).

TABLE 1
NUMBER OF GLOVES OF EACH TYPE OF EACH SIZE

Glove Type	X-Small		Small		Medium		Large		X-Large		Total
	R	L	R	L	R	L	R	L	R	L	
B 7	3	3	3	3	3	3	3	3	3	3	30
B 14	3	3	3	3	3	3	3	3	3	3	30
EB 12.5	3	3	3	3	3	3	3	3	3	3	30
EB 14	3	3	3	3	3	3	3	3	3	3	30
Total	12	12	12	12	12	12	12	12	12	12	120

To control fit differences between glove types within a given size, the hand forms used by the manufacturer to produce the gloves were carefully selected. While perfect within-a-size control might have been achieved by molding all gloves of the same size on the same hand form, this would have involved a prohibitively lengthy period of time. As a compromise, hundreds of hand forms were carefully scrutinized for conformity, to select three for each hand for each size from which the test gloves were made. All glove thicknesses were within \pm 1.5 mil of the thickness specified for this test.

A cotton gauntlet style liner was worn under all gloves (Figure 5). This liner was available in three sizes: Small, Medium, and Large. Twelve of each size were available for this test. The Nomex glove was available in five sizes designated 7 through 11.

Subjects were first asked to select a liner they felt fit them best. Since the liners tended to stretch a great deal, no subjects chose the large size.

Subjects were then offered a choice of glove sizes from one glove type. This glove type was randomly selected from EB 12.5, EB 14 and B 14 types (B 7 is only worn with Nomex and stretches a great deal, so it was not used to select size). Each subject selected the experimental glove which he or she "would feel most comfortable wearing all day for a variety of tasks", and that choice established the subject's size. Subject #1, for example, may have chosen a glove size from the B 14 gloves while subject #2 may have chosen a glove size from the EB 12.5 gloves. Once a size was chosen, subjects wore the same size for all four glove types.

Wearing the liners and the B 7 gloves, subjects selected a Nomex glove size. Despite the elasticity of the Nomex, most subjects chose the larger sizes because of the two layers of gloves already on the hands (see Figure 6). Some of the larger-handed males would have preferred a larger size than any available as even the size 11 was tight across the metacarpal/phalangeal joints.



Figure 5. Glove liners.



Figure 6. Nomex gloves worn over B 7 gloves.

Procedures

A series of practice sessions was conducted for each test. The subject first tried a few rows, bare-handed and untimed. This was followed by a series of six timed practices: two bare-handed; two with one of the three randomly assigned glove types which did not require the Nomex overglove; and the last two with the B 7/Nomex combination. The Nomex overglove fit differently, seemed more restrictive and, as a result, often required a different strategy for performing the tasks from the other three types.

After the practices for a given test were completed, the first of three replicates was run. Each replicate consisted of performing a given test under five conditions (bare-handed and with four glove types). The order of the gloved/bare-handed conditions for each replicate for each subject was randomized. The tasks themselves were always done in the same order--the Pennsylvania and O'Connor tests on the first half day, and the Crawford and Minnesota tests on the second half day. Subjects completed all tests during two half-day sessions, but the time between half-day sessions for a given subject varied from one to 12 days. The variance in time between sessions was not considered important as the practice sessions for a given test were completed within the same session as the test.

The two tests given in each session were alternated between replicates. For example, during the first testing session, all subjects were tested in the following order:

practice and replicate 1 of Pennsylvania
practice and replicate 1 of O'Connor
replicate 2 Pennsylvania
replicate 2 O'Connor
replicate 3 Pennsylvania
replicate 3 O'Connor

Subjects reported that alternating replicates of two tests helped to alleviate boredom as well as muscle cramping. The order of tasks and the randomization of the replicates are illustrated on the data sheet shown in Appendix B.

Each liner and glove was numbered so that when subjects returned for a second day of tests they were given exactly the same gloves and liners to wear.

The subjects were tested two at a time. This, along with posting of record scores, seemed to decrease boredom and to increase motivation.

CHAPTER II

ANALYSIS AND RESULTS

HAND AND GLOVE SIZE

To document the representativeness of subjects with regard to hand size, and to identify any unusual size or proportion that might have caused misleading results, 46 anthropometric measurements (23 for each hand) were taken for each subject (see Appendix C for variable descriptions). Summary statistics for 13 right-hand measurements taken in this study are compared to similar measurements obtained in previous Air Force anthropometric studies in Table 2. The females from the present study are compared to Garrett's (1970a) female hand study and the Air Force anthropometric survey conducted in 1968 (Clauser et al., 1972). The males are compared to Garrett's (1970b) male hand study and the Air Force anthropometric survey conducted in 1965 (Churchill, Kikta and Churchill, 1977). The statistics listed are the sample sizes (n), means, and standard deviations (SD).

Figures 7 and 8 show the location of the test subjects on bivariate frequency distribution tables of the male and female USAF surveys. Each subject's choice of glove size is superimposed on it. The USAF hand breadth distribution was fairly well represented by the subjects in this study (although, as can be seen in Figure 7, one subject had a narrower hand than any found among Air Force males). USAF hand length was not as well represented by the subjects in this study, particularly in the upper ranges of the size distribution, which probably explains why no large gloves were selected. Since this study was concerned with differences in performance due to glove types worn by each subject, and not with differences between subjects, the limited hand length distribution represented by the subjects should not unduly influence the results.

DEXTERITY TESTS

The analysis of the test scores was begun by using Analysis of Variance (ANOVA) tests for eight categories, two sexes by four dexterity tests. Each ANOVA tested the effects of glove type, and glove size-by-type interaction.

No significant ($\alpha=.01$) size by type interaction was found in any of the eight categories. This means differences between glove types are the same regardless of the size the subject was wearing.

Glove type had significant ($\alpha=.01$) effects in each of the eight categories. These effects were analyzed further and the analyses and results are described below.

Glove Type Differences

To determine which glove types were different from each other (bare-handed is treated as a glove type here), a Waller-Duncan ratio test was used.

TABLE 2

COMPARISON OF HAND ANTHROPOMETRY
 (Values in centimeters)

Variable	Present Study Females n=15		USAF Females 1968 n=1905		Garrett Females 1970 n=211		Present Study Males n=15		USAF Males 1965 n=3869		Garrett Males 1970 n=148	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Hand Length	17.66	0.81	†18.38	0.96	17.93	0.86	19.07	0.70	19.70	1.0	19.7	0.9
Hand Breadth	7.38	0.27	7.55	0.39	7.71	0.38	8.51	0.53	8.90	0.5	9.0	0.4
Crotch 1 Ht	5.65	0.49	Not Measured	"	*5.72	0.56	6.11	0.46	Not Measured	"	6.8	0.6
Crotch 2 Ht	9.75	0.58	"	"	*9.86	0.60	10.70	0.62	"	"	*11.0	0.6
Crotch 3 Ht	9.79	0.68	"	"	*9.81	0.59	10.76	0.59	"	"	*10.9	0.6
Crotch 4 Ht	8.69	0.48	"	"	*8.72	0.60	9.57	0.52	"	"	*9.7	0.5
Digit 1 Length	10.90	0.56	"	"	*11.50	1.00	11.65	0.74	"	"	Not Measured	"
Digit 2 Length	16.56	0.72	"	"	*16.67	0.89	17.75	0.73	"	"	*18.3	0.9
Digit 3 Length	17.66	0.81	"	"	*17.65	0.87	19.07	0.70	"	"	*19.5	0.9
Digit 4 Length	16.46	0.89	"	"	*16.76	0.89	17.99	0.67	"	"	*18.2	0.9
Digit 5 Length	13.92	0.72	"	"	*14.64	0.92	15.29	0.78	"	"	Not Measured	"
Hand Circ	18.13	0.67	18.32	0.91	18.71	0.83	20.87	1.20	21.50	1.0	21.6	0.9
Hand Thickness - Metacarpale III	2.59	0.15	Not Measured	"	2.76	0.18	2.92	0.20	Not Measured	"	3.29	0.2

† Measured from the level of the radial styloid; in the other studies, from the wrist crease.

* Garrett measured with digits separated. They were together for the present study.

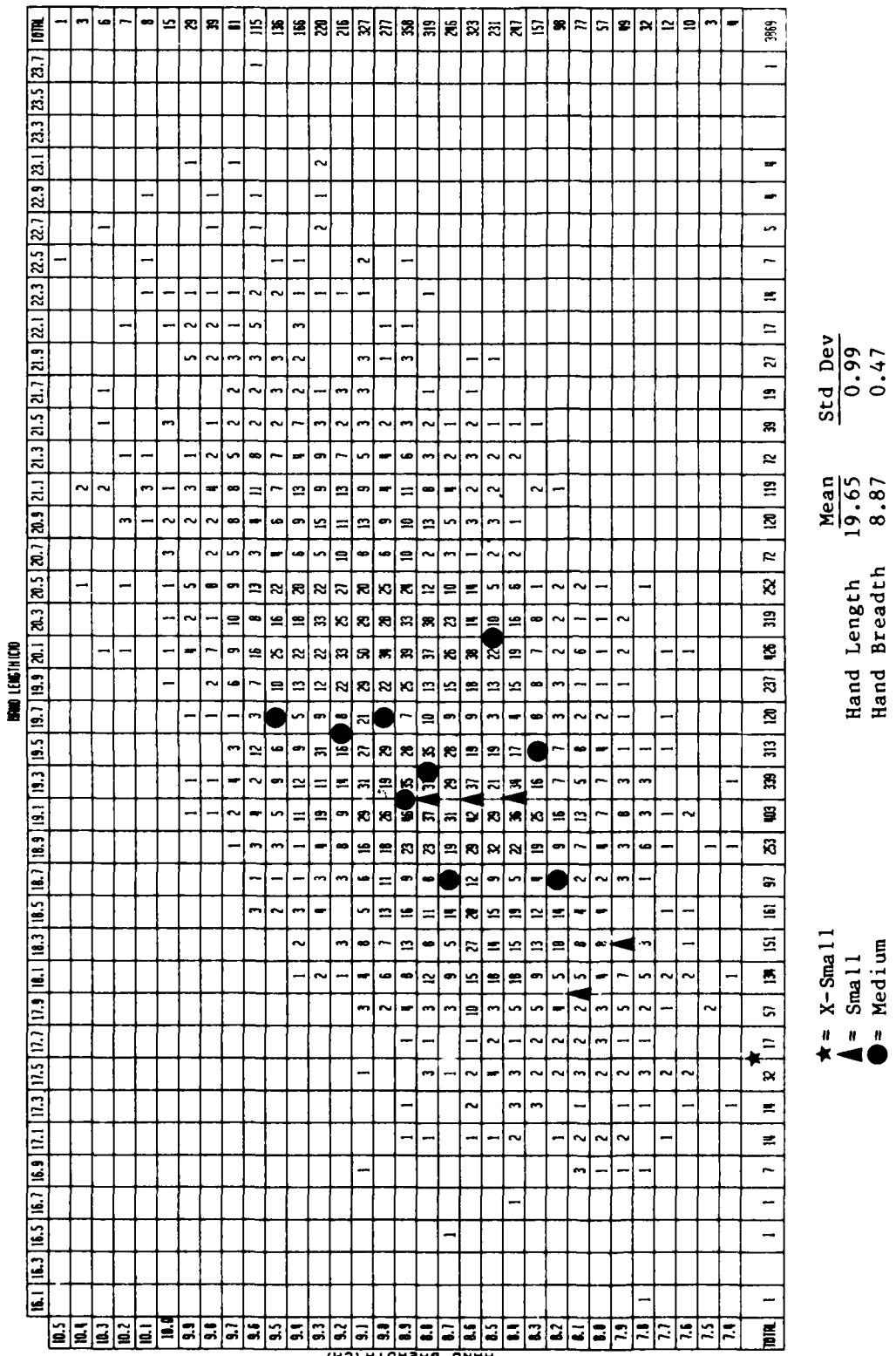


Figure 7. A bivariate frequency distribution for hand length and hand breadth for the 1965 U.S. Air Force males (Churchill, Kikta and Churchill, 1977) on which the male test subjects are located with glove size choice for each superimposed.

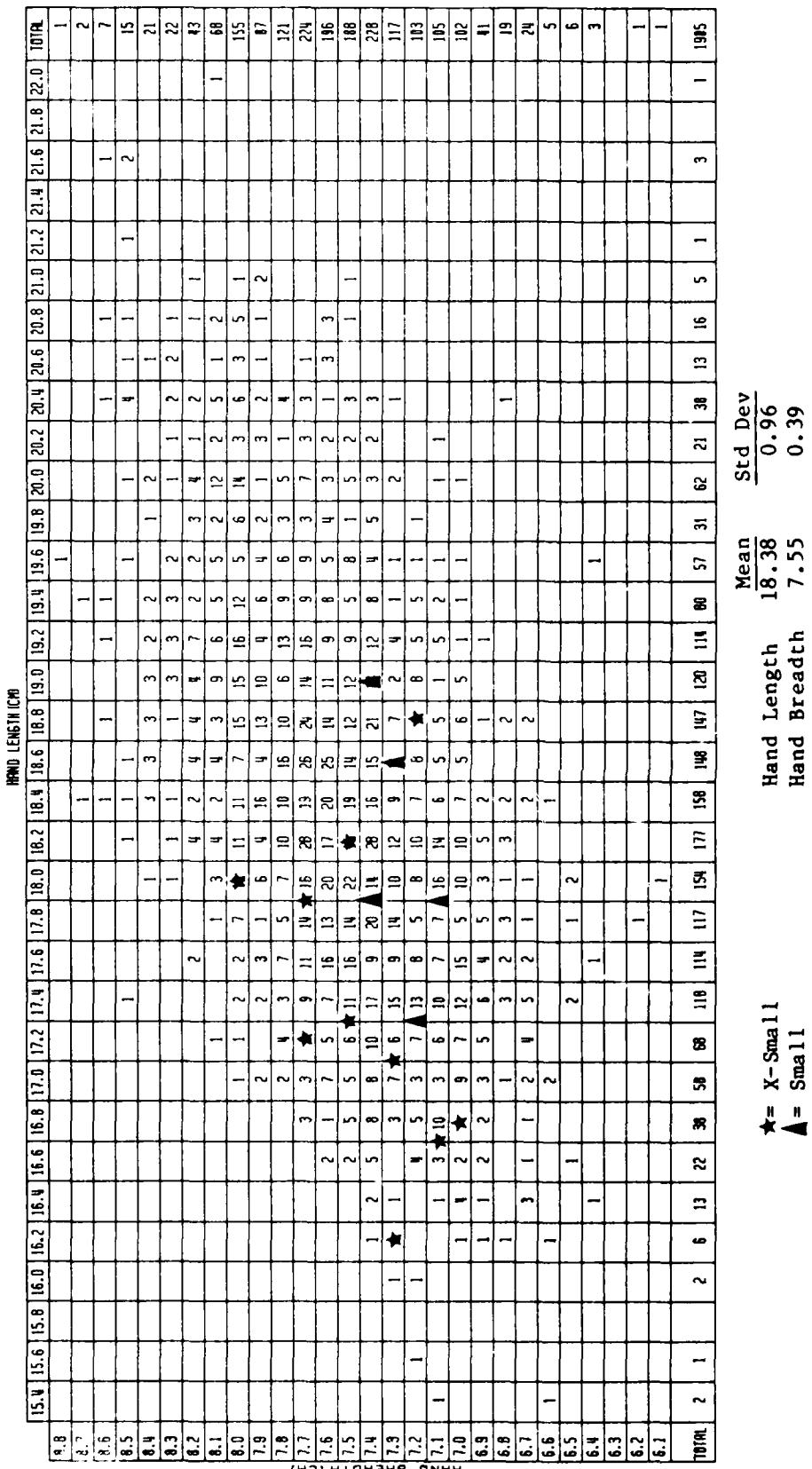


Figure 8. A bivariate frequency distribution for hand length and hand breadth for the 1968 U.S. Air Force females (Clauser et al., 1972) on which the female test subjects are located with glove size choice for each superimposed.

Table 3 lists the results for males, Table 4 the results for females. In each table, the test type is shown in the first column at the left, and the glove type is shown across the top. Within the table, mean scores for each glove type for each test are shown. Below the means are the results of the Waller-Duncan Test which indicate if the differences between the means are statistically significant. Means with the same letter are not significantly different ($\alpha=.05$). For example, on the O'Connor test, for males, the bare-handed condition and the B 7/Nomex were significantly different from all others as indicated by the letters D and A. The EB 12.5 and the EB 14 are not significantly different from each other as indicated by the shared letter C; similarly, the EB 14 and the B 14 are not significantly different from each other as indicated by the letter B, while the EB 12.5 and the B 14 are significantly different as indicated by the letters C and B, respectively.

As can be seen, both male and female subjects performed significantly better bare-handed when compared to all the gloved conditions, and performance with the B 7/Nomex glove combination was significantly the worst for all conditions. Not surprisingly, this result was found for all tests.

On the O'Connor test, males performed best with the EB 12.5, followed by the EB 14 and the B 14. The difference between the EB 12.5 and the B 14 was statistically significant at $\alpha=.05$. For the females the order of the test scores was the same as for the males but the difference between the scores was not statistically significant.

On the Pennsylvania test, males performed significantly better with the EB 12.5 and EB 14 gloves than with the B 14 gloves. The order of performance for females was the same but again the difference between the gloves was not significant.

The results of the Minnesota tests showed that males performed better with the EB 12.5, followed by EB 14 and B 14. The EB 14 was not significantly different from the other two, but the EB 12.5 and B 14 were significantly different. On the Minnesota the order of the females' performance was the same but all scores were significantly different from each other.

Neither the males nor females showed any significant differences between the EB 12.5, EB 14, or B 14 gloves on the Crawford test.

In summary, performance with the EB gloves, no matter which thickness, appeared to be slightly better than performances with the B 14 glove. Some subjects reported that the B 14 glove felt stiffer than the EB 14 glove. Thickness measurements were taken on EB 14 and B 14 gloves and no consistent differences were found. The investigators found, however, that after testing, both the EB gloves showed signs of wear especially on the fingertips, whereas B 14 did not.

Fit Analysis

Correlations between anthropometry and test scores of subjects wearing EB 12.5, EB 14, and B 14 gloves were studied. The results showed a large number of

TABLE 3
WALLER-DUNCAN TEST RESULTS FOR MALES
n=15
(Response time in seconds)

<u>Test</u>	<u>Bare-Handed</u>	<u>EB 12.5</u>	<u>EB 14</u>	<u>B 14</u>	<u>Butyl 7/ Nomex</u>
O'Connor:					
Mean Response Duncan	157.47 D	191.22 C	197.20 CB	206.02 B	237.71 A
Pennsylvania:					
Mean Response Duncan	125.69 D	165.56 C	172.78 C	182.87 B	219.87 A
Minnesota:					
Mean Response Duncan	35.38 D	41.16 C	43.07 BC	43.38 B	49.51 A
Crawford:					
Mean Response Duncan	148.73 C	196.93 B	195.93 B	193.91 B	230.07 A

TABLE 4
WALLER-DUNCAN TEST RESULTS FOR FEMALES
n=15
(Response time in seconds)

<u>Test</u>	<u>Bare-Handed</u>	<u>EB 12.5</u>	<u>EB 14</u>	<u>B 14</u>	<u>Butyl 7/ Nomex</u>
O'Connor:					
Mean Response Duncan	145.20 C	185.91 B	193.04 B	195.20 B	241.67 A
Pennsylvania:					
Mean Response Duncan	133.84 C	174.56 B	178.78 B	183.47 B	243.07 A
Minnesota:					
Mean Response Duncan	34.69 E	41.60 D	43.89 C	46.49 B	53.04 A
Crawford:					
Mean Response Duncan	178.36 C	231.62 B	231.40 B	233.04 B	293.67 A

negative correlations, ranging from -.40 to -.75 (significant at $\alpha=.0001$), between finger circumferences and scores for the women in size X-Small. The negative correlations indicate that the smaller the finger the higher (or worse) the dexterity score. No significant correlations were found between bare-handed test scores and anthropometry. This indicates that fit in the fingers significantly affected the test scores for the women.

For the men, there were also no significant correlations between bare-handed test scores and anthropometry. However, there were significant negative correlations, ranging from -.41 to -.91 between finger lengths and dexterity scores in the Small and Medium sizes, when the subjects were wearing the EB 12.5, EB 14, or B 14 gloves. This indicates that the lengthwise fit in the fingers significantly affected performance for the men.

Replicate Evaluation

A brief evaluation of the experimental design was done to determine if the controls for learning were effective. Except for one comparison (for males on the Pennsylvania Test), there was a significant difference between replicate 1 and replicate 2 which indicates the subjects were still learning to perform the tests. However, only one significant difference was found between replicate 2 and replicate 3. This was for males on the Minnesota test. In all cases, there was no interaction between replicates and glove type. In other words, no matter which replicate, the effect of the gloves was the same. These results suggest that the three-replicate design was adequate for controlling learning effect, although in future studies the addition of one more practice session might be considered.

Conclusions

The comparison of the four glove types produced several important findings. First, all the gloves impeded dexterity/tactility when compared to bare-handed performance. Also, of all glove types compared, the B 7/Nomex combination was significantly worse for both sexes on all tests. In addition, it was difficult to fit male subjects properly with the Nomex size-range provided. The largest size available was size 11, and several of the males with larger hands complained that the gloves were too tight across the back of the hands. Because the subjects were actually wearing three layers of gloves (liner, B 7, and Nomex), the gloves tended to slide off slightly, creating extra fingertip space and subjects often had to pull them back on during testing.

Of the three other glove types, performance of the subjects was always better (though not always significantly) with EB gloves than with the B 14 gloves. Of the EB gloves, the thinner one (EB 12.5) seemed to impede performance less. The EB gloves, however, tended to show signs of wear after use (discoloring, small holes or bubbles in fingertips) and the B 14 gloves did not. Subjects often stated that the Butyl 14 felt stiffer and many preferred the EB 12.5.

The fit of the EB 12.5, EB 14, and B 14 types apparently affected the ability of the subjects to perform the tests. For the men, the looser the fit in finger length the worse the performance. They could have selected a smaller size, but they were asked to choose the size which was the most comfortable--that is, the size they felt fit them best. This indicates that even with the "best fitting size", there was still a fit problem. For the women, the looser the fit in finger circumference the worse the performance. Like the male subjects, the women were asked to select the size they felt fit them best. Of the 15 subjects, 10 chose size Extra-Small. Therefore, it appears that the dexterity/tactility properties of chemical defense gloves could be improved with a better sizing system.

APPENDIX A
GENERAL INSTRUCTIONS
FOR DEXTERITY TEST SUBJECTS

Today we are testing four types of gloves. Note, we are not testing you. We will ask you to do a series of tests while wearing each of the different gloves and bare-handed. We want you to do the tests as fast as you can but we also want your technique and speed to be as consistent as possible. Therefore, we will have you practice while we time you, until your scores are consistent. We will also measure your hand and ask you questions about the gloves in an attempt to ascertain glove fit problems. We'd also appreciate any comments you may have about the tests themselves.

Pennsylvania Bi-Manual Assembly

Instructions:
(adjust table to seated position)

This test is called the Pennsylvania Bi-Manual Assembly Test. It is a speed test measuring how quickly you can attach a nut to a bolt and place it in a hole, like this (demonstrate). Though there are ten rows, you will be asked to fill four rows only. You begin by arranging the board so that the bolts are closest to your dominant hand. Use your opposite hand to pick up the nut and to place the nut and bolt in the corner farthest from your dominant hand. If a nut falls into a hole, go on to the next. The observer will remove the first combination which you will then replace.

Practice:

You will practice six times using one row, bare-handed, and with two types of gloves. You begin with your hands in the wells, with a part in each hand. There are enough extra so that if you drop one, pay no attention to it but go right ahead. Try a row before we begin.

O'Connor Finger Dexterity Test

Instructions:
(adjust table to seated position)

Arrange the board so the pins are at the top. With your dominant hand, pick up three pins at a time and place all three in one hole, beginning with the top corner opposite your dominant hand. You must get three pins in a hole. If one or more is dropped, you may go back and get more; in other words, you don't have to pick up those dropped. In fact, it will be time-saving in most instances to go back to the original pile rather than to try to pick up pins which have been dropped. Once three are in each hole, don't worry if you knock them out. Just leave them. You may use your other hand to

steady the board if you like. Start with the first set of pins in your fingers. For the actual test you will complete four rows on the board (down to the taped row).

Practice:

For practice, you will do one row six times, bare-handed and with two types of gloves. Before we start, try a row to get the feel of the test.

Crawford Small Parts Dexterity Test-Screws

Instructions:

(adjust table to seated position)

This test is called the Crawford Small Parts Dexterity Test-Screws. It is a speed test measuring how quickly you can insert screws in a hole using a small screwdriver. Though there are six rows, you will be asked to fill the first two rows only. Start each row in the hole opposite your dominant hand. You begin by placing your dominant hand in the screw well, picking up a screw, and using your other hand to hold the screwdriver. Use your dominant hand to begin the screw and use the screwdriver to turn each screw until you hear it hit the metal plate below.

Practice:

You will practice six times, using one row only, bare-handed, and with two types of gloves. There are enough screws so that if you drop one, please ignore it and continue. Try a row before we begin.

Minnesota Rate of Manipulation Turning Test

Instructions:

(adjust table to standing position)

For this test the object is to see how fast you can turn the blocks over. You do it like this (demonstrate). With your left hand, lift the block from the upper right-hand hole and, with your right hand, put it back, bottom side up, into the same hole. Work to the left across the board, picking up the blocks with your left hand, and putting them down with your right, bottom side up. As you work back to the right in the next row, pick them up with your right hand and put them down with your left. Always pick up the blocks with the hand that leads, and put them down with the hand that follows. Before you finish, be sure that every block is all the way down. Start with your left hand on the first block. If a block is dropped on the floor, the test will be started over.

Practice:

For practice you will do the entire board six times, bare-handed, and with two types of gloves. Try a row before we begin.

APPENDIX B

DEXTERITY TESTING OF CHEMICAL DEFENSE GLOVES DATA SHEET

DEXTERITY EVALUATION OF CD GLOVES

PHASE II DATA

Name _____ Handedness: Right Left
Subject No. _____ Glove Size _____
Sex: Male Female Liner Size _____
Age _____ Nomex Size _____
Date _____ Prior Testing _____

Anthropometry

	Left	Right	Left	Right
Hand Breadth	_____	_____	Digit 1 Circ	_____
Hand breadth w/Thumb	_____	_____	Digit 2 Circ Base	_____
Hand Depth MPJ	_____	_____	Digit 2 Circ Tip	_____
Crotch 1 Height	_____	_____	Digit 3 Circ base	_____
Crotch 2 Height	_____	_____	Digit 3 Circ Tip	_____
Crotch 3 Height	_____	_____	Digit 4 Circ base	_____
Crotch 4 Height	_____	_____	Digit 4 Circ Tip	_____
Digit 1 Length	_____	_____	Digit 5 Circ base	_____
Digit 2 Length	_____	_____	Digit 5 Circ Tip	_____
hand Length	_____	_____	hand Circ	_____
Digit 4 Length	_____	_____	hand Circ w/Thumb	_____
Digit 5 Length	_____	_____		

Glove Number

	Left	Right
Eco/Butyl 12.5	_____	_____
Eco/Butyl 14	_____	_____
Butyl 7	_____	_____
Butyl 14	_____	_____

What did you think of the glove fit? _____

Did you notice any differences in material? _____

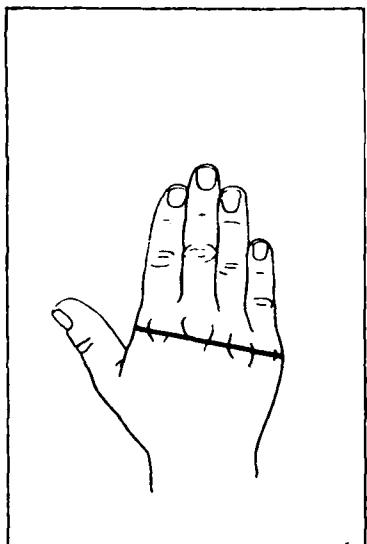
What did you think of the tests? _____

Comments: _____

PHASE II DATA (cont'd)

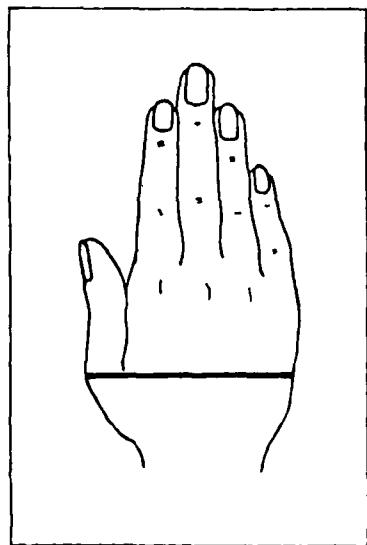
	<u>Pennsylvania Bi-Manual</u>	<u>Trials</u>	<u>Tests</u>		
1	No gloves		4	5	2
—	Eco/Butyl 12.5		1	1	5
2	Eco/Butyl 14		3	4	4
3	Butyl 7 & Nomex		5	2	3
—	Butyl 14		2	3	2
<u>O'Connor</u>					
1	No gloves		1	3	2
—	Eco/Butyl 12.5		2	2	4
2	Eco/Butyl 14		3	4	5
3	Butyl 7 & Nomex		5	5	3
—	Butyl 14		4	1	1
<u>Crawford</u>					
1	No gloves		1	4	4
—	Eco/Butyl 12.5		4	1	2
2	Eco/Butyl 14		2	5	1
3	Butyl 7 & Nomex		3	3	5
—	Butyl 14		5	2	3
<u>Minnesota Turn & Place</u>					
1	No gloves		2	4	5
—	Eco/Butyl 12.5		5	5	3
—	Eco/Butyl 14		1	3	4
3	Butyl 7 & Nomex		4	1	2
2	Butyl 14		3	2	1

APPENDIX C
VISUAL INDEX OF HAND DIMENSIONS



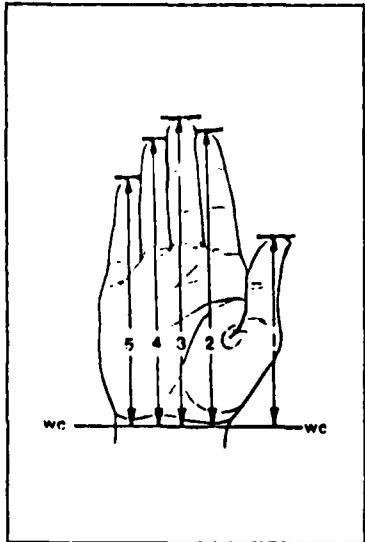
HAND CIRCUMFERENCE

Subject's hand is extended, palm down, thumb held away from the fingers. With the tape passing over metacarpal-phalangeal joints II and V, measure the circumference of the hand.



HAND CIRCUMFERENCE WITH THUMB

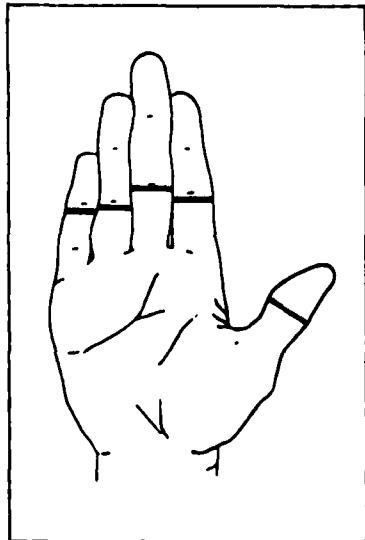
Subject's hand is extended, palm down, thumb held close to the fingers. With the tape passing over the metacarpal-phalangeal joint I, measure the circumference of the hand perpendicular to its long axis.



DIGIT LENGTHS

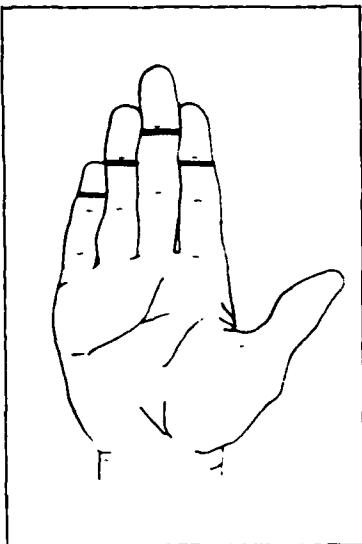
With the digits adducted, measure the perpendicular distance from the wrist crease base line to the midpoint of the tip of each digit. Digit III length is called Hand Length here.

WC = wrist crease



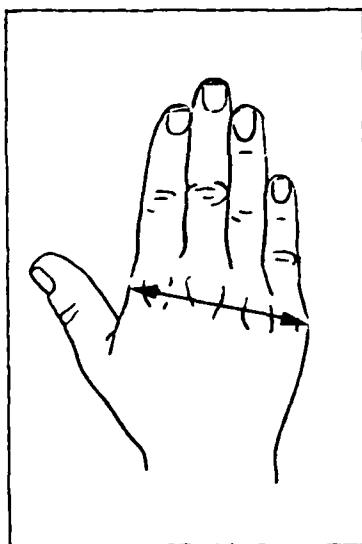
DIGIT CIRCUMFERENCE AT BASE

Subject's hand is extended, palm up. With the tape, measure the circumference of the digits at the most proximal crease of the proximal interphalangeal joints II - V and the interphalangeal joint I.



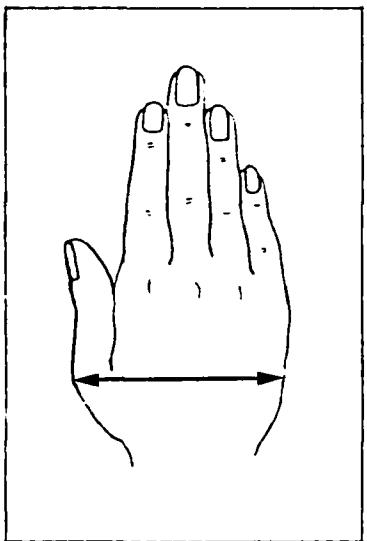
DIGIT CIRCUMFERENCE AT TIP

Subject's hand is extended, palm up.
With the tape, measure the circumference
of the finger distal to the distal inter-
phalangeal joint creases II - V.



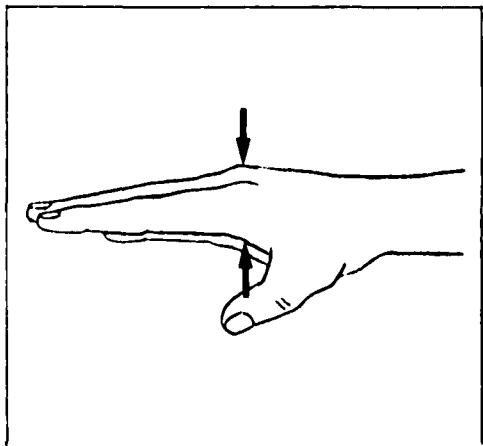
HAND BREADTH

Subject's hand is extended, palm down,
thumb held away from the fingers.
With the bar of the sliding caliper lying
across the back of the hand, measure the
breadth of the hand between metacarpal-
phalangeal joints II and V.



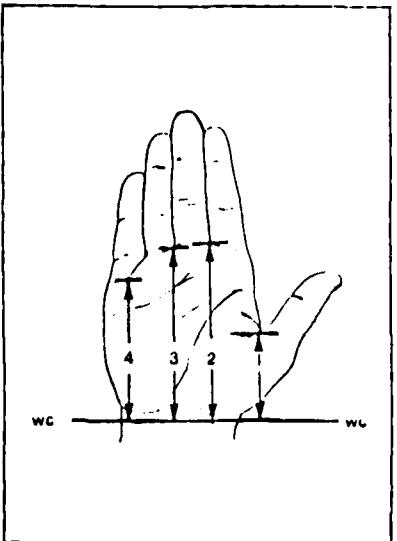
HAND BREADTH WITH THUMB

Subject's hand is extended, palm down, thumb held close to fingers.
With the bar of the sliding caliper, measure the breadth of the hand, perpendicular to its long axis at the level of the metacarpal-phalangeal joint I.



HAND DEPTH

Subject's hand is extended, fingers adducted. With the sliding caliper, measure the maximum thickness of the metacarpal-phalangeal joint III.



CROTCH HEIGHTS

With the fingers adducted and the thumb abducted, measure the perpendicular distance from the wrist crease base line to the level of the hand crotches.

Digit 5 was occasionally abducted to determine the correct location of the crotch prior to measuring.

WC = wrist crease

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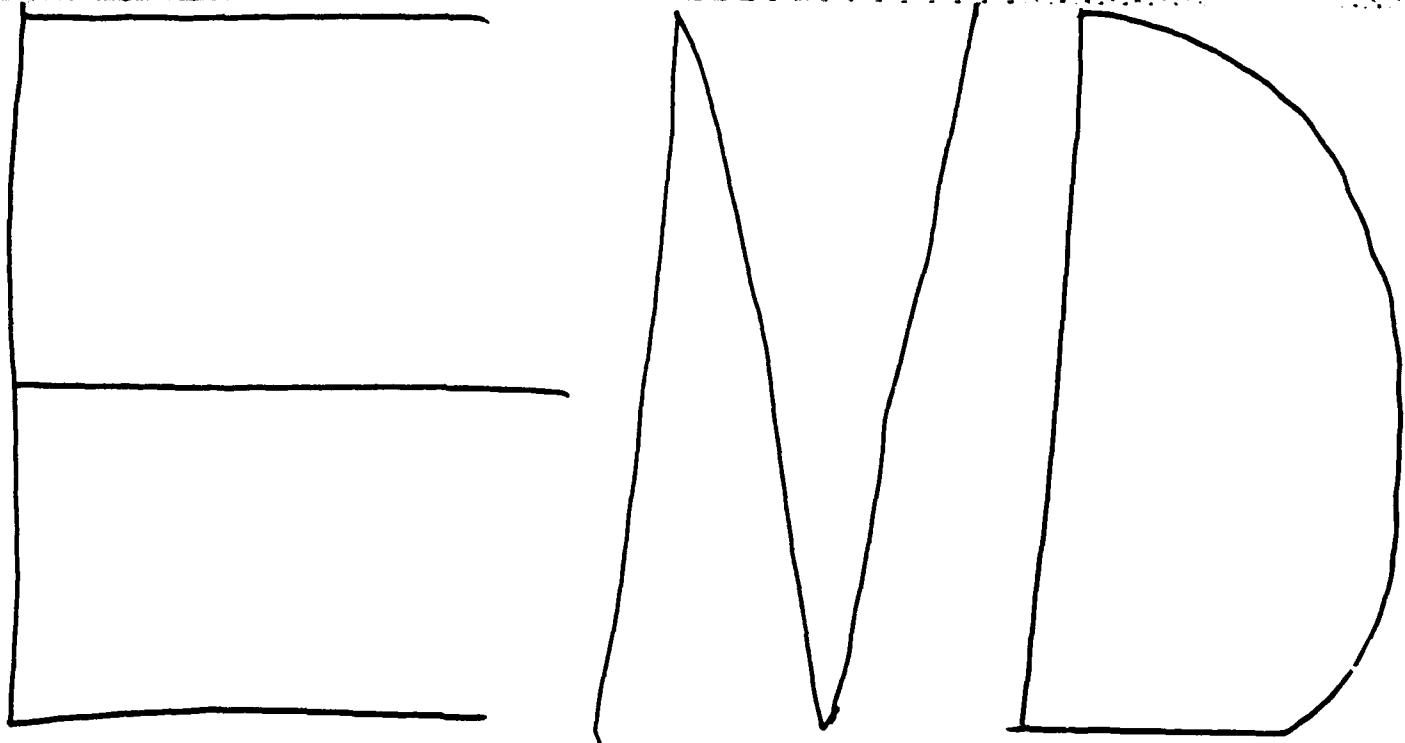
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